PHOTOCONDUCTIVE FREQUENCY AGILE GaAs IMPULSE DEVICE

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ABSTRACT

The feasibility of generating frequency agile impulses has been successfully demonstrated using a monolithic, photoconductive GaAs impulse device. Two time-delayed optical pulses from a mode-locked Nd:YAG laser, delivered by two different lengths of optical cables, were used to turn-on and turn-off the device. The time interval between the "on"-laser pulse and the "off"-laser pulse was varied, resulting in a corresponding change in the output electrical pulsewidth which ranged from 2.1 ns to 4.9 ns.

INTRODUCTION

There has been a great deal of research activity in the generation of high peak power impulses, often referred to as ultra-wideband technology and impulse technology. The interest in this technology stems from its potential applications such as impulse radars and impulse communications. The technology relies on the generation of short-duration pulses with sub-nano second risetimes. The fast risetime, high peak power pulses are routinely generated using either photoconductive semiconductor switches [1], fast turn-on spark gaps [2], or ferrite pulse sharpening techniques [3]. In general, these techniques produce a fixed output pulsewidth.

The free-space transmission of an impulse, having very high peak power, produces a frequency spectrum that extends from near DC to several gigahertz. Since the radiated RF energy is spread out in a wide range of the frequency spectrum, the radiated energy per unit frequency spectrum is small. However, many practical applications require maintaining a certain energy level over the range of frequency spectrum. This may be achieved by generating an extremely high peak power impulse, using a new impulse generating technique in which the center frequency of the radiated RF signal can be varied by changing the pulsewidth of the output electrical impulse. Here, this new technique in which the output electrical pulsewidths are varied is presented and discussed.

OPERATING PRINCIPLE

The monolithic, photoconductive GaAs pulser [4], shown in Fig.1, consists of a circular GaAs wafer, typically 7.5 cm in diameter, with metalized disc electrodes on each side. Depending on the device design, the device is operated in two modes. When the spacing between the concentric electrodes on the ground side is wide enough, the output tail from this device shows the normal capacitive decay. However, when the spacing is narrowed to 2 mm or less, the device exhibits self-initiated current turn-off properties. A possible explanation of the observed behavior is an avalanche between the inner and outer radii of the GaAs output region, causing the current to interrupt, and, thus, giving rise to a very narrow pulse. Such a device (with a 2 mm inner radius), operating in the current quenching mode, produced a 5 kV impulse with a pulsewidth of 500 ps.

A third mode of operation is a combination of the first and the second modes of operation. Rather than fabricating the electrodes with narrow spacing and operating the device in a self-initiated current turn-off mode, a device with a wider spacing was fabricated and operated in the new mode. In this mode of operation, the device is turned on, as in the first mode of operation, by the initial optical pulse from a mode-locked Nd:YAG laser. Following the initial optical pulse, a delayed, second optical pulse is then introduced to shut down the current flow, by shorting out the output region between inner and outer conductors. This approach enables control of the output electrical pulsewidth by changing the time delay between optical pulses.

EXPERIMENTAL RESULTS AND DISCUSSION

Fig.2 shows the experimental set-up. The operating sequence involves first charging up the device using an SCR-transformer pulser. Once the charging process is completed, the two optical pulses from a mode-locked Nd:YAG laser are used sequentially to turn-on and turn-off the device. The first optical light, conveyed by the fiber optic cable with length of L, is used to turn on the device. Meanwhile, a time delayed second laser pulse, conveyed by the fiber optic cable with length $L + \Delta L$, is used to short circuit the device output during the discharging cycle. The output pulse was obtained using a Textronix SCD-5000 oscilloscope.

Figs. 3, 4, 5, and 6 are the output pulses (into 50 Ω) from a 3-mm thick GaAs device when illuminated with a 75-ps wide optical pulse from the mode-locked Nd:YAG laser. The waveform in Fig.3 is obtained without interruption by the second optical pulse. The output waveforms in Figs.4, 5, and 6 on the other hand, demonstrate current interruption for various time delays. The delays employed were L = 62 cm, 41 cm, and 21 cm, respectively. The calculated delay times corresponding to the additional fiber lengths were 3.0 ns,

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The feasibility of generating frequency agile impulses has been successfully demonstrated using a monolithic, photoconductive GaAs impulse device. Two time-delayed optical pulses from a mode-locked Nd:YAG laser, delivered by two different lengths of optical cables, were used to turn-on and turn-off the device. The time interval between the "on"-laser pulse and the "off’’-laser pulse was varied, resulting in a corresponding change in the output electrical pulsewidth which ranged from 2.1 ns to 4.9 ns.

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2.0 ns, and 1.0 ns, respectively. Under normal conditions, where a positive mismatch impedance condition exists and only a single triggering optical pulse is used, the impulse generating device utilizing a non-uniform radial transmission line structure behaves as an RF capacitor. The peak amplitude of the output pulse is nearly same as the bias voltage, due to the impedance transformation property of the radial line. The output pulse shape has a very fast risetime and the usual capacitive slow falltime. The peak amplitude of the output pulse, shown in Fig.3, is 4 kV and its measured decay time constant is about 15 ns. By interrupting the device with a time delayed second optical pulse, using an additional fiber optic cable length of L = 62 cm, the result (Fig. 4) was an output pulse with a pulsewidth of 4.6 ns. When L was reduced to 41 cm, the output pulse (Fig. 5) had an output pulsewidth of 3.5 ns. With further reduction of L to 21 cm, the output pulsewidth, shown in Fig. 6, became 2.1 ns.

In summary, a new mode of device operation has been achieved by introducing a time delayed second optical pulse. The introduction of the time delayed second optical pulse into the gap between the inner and outer conductors (at the ground side electrode) causes the interruption of the normal capacitive decay by creating a transverse conducting path. Once the transverse conducting channel is complete, the device output becomes a short circuit and this results in the generation of high peak power, narrow pulses with various pulsewidths. The calculated pulsewidth tends to underestimate the measured pulsewidth. That is probably due to the finite time required for the avalanche to make a complete transverse conducting path after the time delayed second optical pulse arrives.

CONCLUSION

A new impulse device has been successfully demonstrated using a photoconductive GaAs device in the form of a radial line. Two time delayed optical pulses were used to tailor the pulsewidth of the output. 4-kV pulses, ranging in pulsewidth from 2.1 ns to 4.9 ns were generated.

REFERENCES

1. M. D. Pocha, and R. L. Druce, "35 kV GaAs subnanosecond photoconductive switches," IEEE Trans. ED, vol.37, No.12, pp. 2473-2492, Dec. 1990.

2. L. F. Rinehart, M. T. Buttram, W. R. Crowe, R. S. Clark, J. M. Lundstrom, and P. E. Patterson, "An Enantiomorphic Blumlein Impulse Generator," Proceedings of the 1992 Twentieth IEEE Power Modulator Symposium, pp. 126-129.

3. D. Birx, , and J. R. Fishback, "High Power, 10 kHz Repetition Rate Ultra-wideband Source Development at the U.S. Army's Missile Command," 1992 IEEE MTT-s International Microwave Symposium Digest, Vol. 3, 1992, pp. 1605-1608.

4. A. Kim, R. Zeto, R. Youmans, J. Conrad, C. Kondek, and M, Weiner, H. Brisker, J. Agee, L. Jasper, and B. Lalevic, "Monolithic, Photoconductive Impulse Generator Using a GaAs wafer,' Appl. Phys. Lett. 58, 2812 (1991).

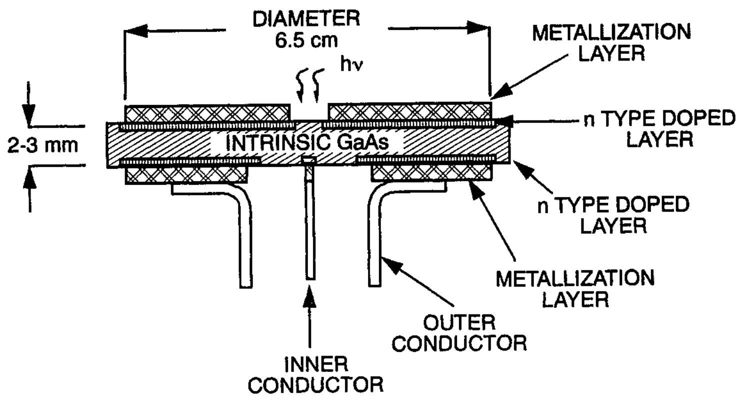
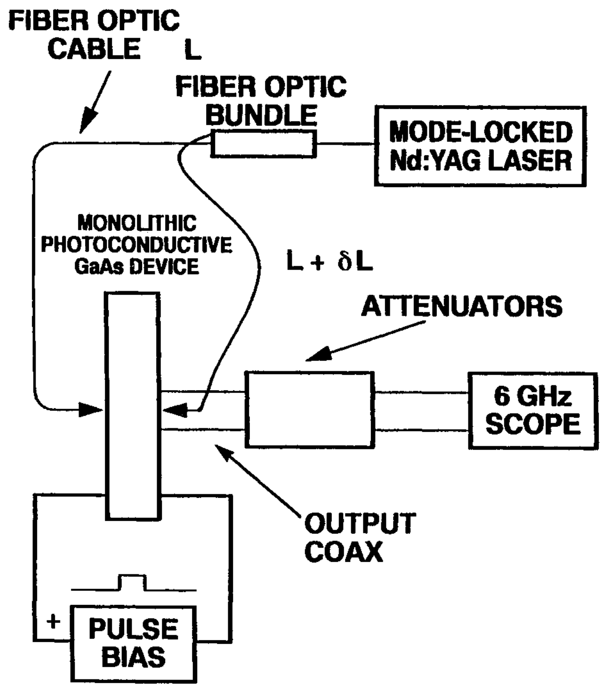


Figure 1 Side view of monolithic GaAs device.



Fiure 2 Test set-up for measuring output waveforms.

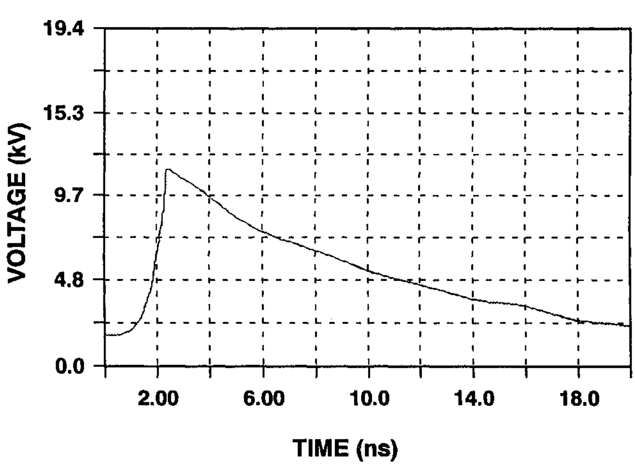
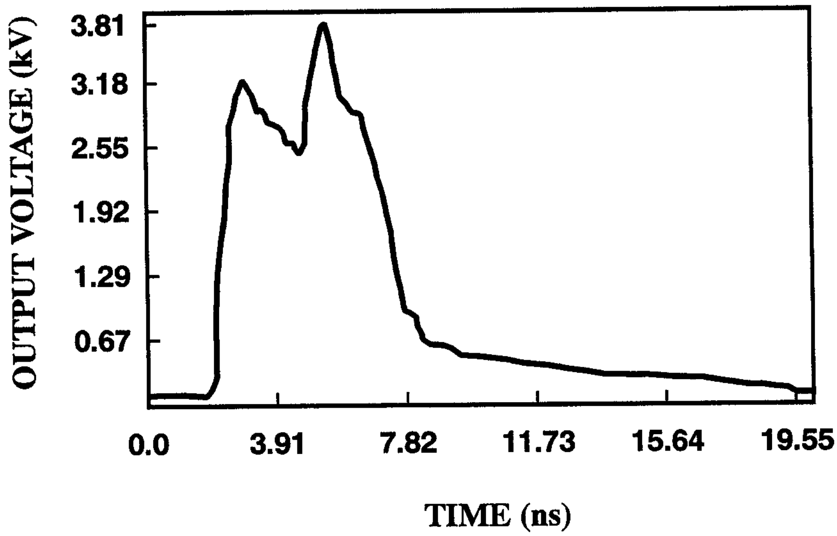


Figure 3 Output pulse width no interruption.



Fiq.4 Output pulse with dL = 58 cm.

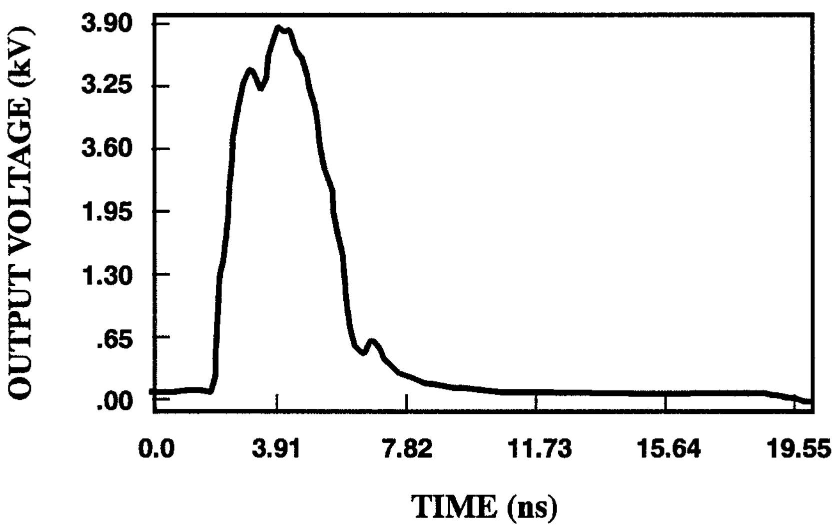


Fig.5 Output pulse with dL = 27 cm.

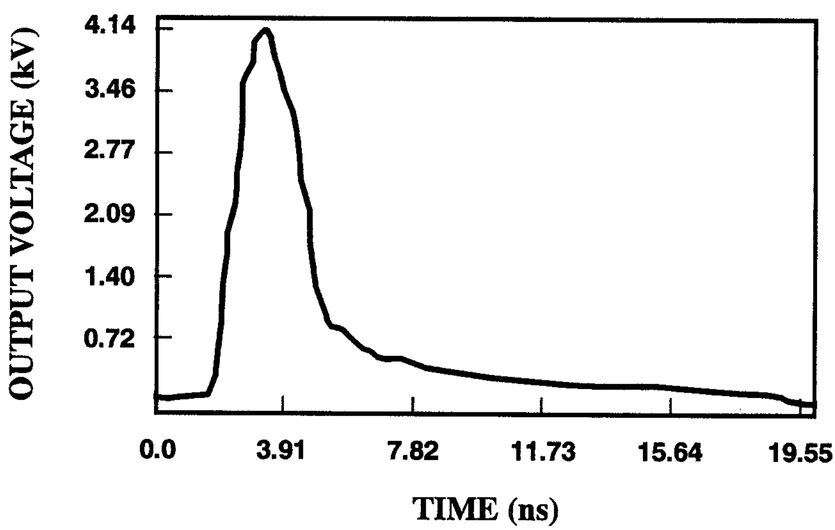


Fig.6 Output pulse with dL = 17 cm.